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Benefits of an external focus of attention:

Common coding or conscious processing?

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Key words: Explicit, Implicit, knowledge, golf putting, motor learning

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Abstract

Two experiments were conducted that examined the effect attentional focus has on learning a complex motor skill and subsequent performance under secondary task load. Participants in Experiment 1 learnt a golf putting task (300 practice trials) with a single instruction to either focus on their hands (internal focus) or the movement of the putter (external focus). No group differences were evident during learning or in retention. Differences between the groups were only apparent under secondary task load; the external group's performance remained robust whilst the internal group suffered a drop in performance. Verbal protocols demonstrated that the internal group accumulated significantly more internal knowledge and more task relevant knowledge in general than the external group. Experiment 2 was designed to establish whether greater internal focus knowledge or greater explicit rule build up in general was responsible for performance breakdown. Two groups were presented with a set of six internal or external rules. Again, no performance differences were found during learning or retention. During secondary task both groups experienced performance deterioration. It was concluded that accumulation of explicit rules to guide performance was responsible for the internal group's breakdown in performance under secondary task loading and may be responsible for some of the performance differences reported previously.

Introduction

For many years it has been a popular opinion in sports coaching that in order to acquire and execute particularly complex motor skills a performer must know what they are doing; that is, a substantial declarative knowledge base is required during the initial stages of learning. Only when the learner becomes proficient can performance take place automatically without reference to this explicit reservoir of information (Anderson, 1982). However, evidence is accumulating to support the premise that presenting a performer with a large explicit knowledge base through learning is, paradoxically, not the most productive method of acquiring a motor skill (Masters, 1992; Wulf and Weigelt, 1997; Maxwell, Masters and Eves, 2000; Maxwell, Masters, Kerr and Weedon, 2001; Liao and Masters, 2002; Maxwell, Masters and Eves, 2003). Consequently, investigation of the type of instructions that promote learning efficiency is increasing.

One theoretical approach has been to consider the focus of attention of the learner. Wulf and her colleagues, for example, have argued that focusing attention on the effects of body movements (external focus) rather than on the movements themselves (internal focus) is more efficacious for the acquisition of new movement skills (for a review see Wulf and Prinz, 2001). Their conceptualization evolved from Prinz's (1990; 1997) common coding principal, which postulates that in order for actions to be effective, afferent and efferent information must exhibit a high degree of compatibility; therefore, movements need to be planned in terms of their desired outcome, or in other words, their effect (Prinz, 1997).

The advantageous nature of an external focus was first reported by Wulf, Höß, and Prinz, (1998) using a ski-simulator task. It was found that directing performers' attention externally to the effect their movement had on the apparatus produced superior performance throughout learning and in delayed retention than both instructions to focus on the outer foot (internal focus), and no attentional instructions (discovery learning control group). In a second experiment, the beneficial effect of directing attention externally was further examined in a stabilometer balancing task. Deviation from horizontal was greatest for the internal focus group during a retention test, further illustrating the benefits of an external focus of attention and in concordance with Prinz's (1997) common coding principal.

The basic finding that external focus instructions, relative to internal focus and no instructions, enhance retention performance on dynamic balance tasks has since been replicated several times (Shea and Wulf, 1999; Wulf, McNevin and Shea, 2001; McNevin, Shea and Wulf, 2003). These findings have also been generalized to more complex motor skills, such as golf chipping (Wulf, Lauterbach and Toole 1999), tennis (Wulf, McNevin, Fuchs, Ritter and Toole, 2000), volleyball and soccer (Wulf, McConnel, Gärtner and Schwarz, 2002). Generally, external focus instructions enhance complex skill performance in novices when measured during both learning and delayed retention tests (Wulf *et al.* 2001).

McNevin *et al.* (2003) postulated that advantages associated with external focus of attention arise as a consequence of the 'utilization of more natural control mechanisms' (p22). This postulate led to the formation of the constrained action hypothesis, which states that 'conscious attempts to control movements interfere with automatic motor control processes, whereas focusing on the movement effects allows the motor system to self-organize more naturally, unconstrained by conscious control' (Wulf, Shea and Park, 2001, p. 342). The theory implies that external focus instructions promote the automatic processing of information subsuming motor control; whereas, focusing on the movements themselves elevates this information to the level of conscious control, presumably by working memory (Baddeley and Hitch, 1974; Baddeley, 1986).

To test this proposition, Wulf *et al.* (2001) used probe reaction time to measure the relative attentional demands of external and internal focus learners. Probe reaction time was expected to be slowed by the need to process information consciously; therefore, external focus learners were expected to respond quicker than internal focus learners. Superior (shorter) reaction time performance was evidenced by external focus learners, which was interpreted as representing the availability of attentional resources, implying greater automaticity. Additionally, mean power frequencies computed from Fast Fourier Transform analyses indicated movement frequency adjustments that were higher in frequency and smaller in amplitude in the external focus condition relative to the internal focus condition, again reflecting greater automaticity.

It appears that external focus instructions enhance learning by promoting the integration of effector and perceptual processes, thereby promoting automaticity of movement control; whereas, focusing internally introduces conscious elements that interfere with normal, automatic movement control. Recently, however, a number of reports (Maxwell and Masters, 2002; Perkins-Ceccato, Passmore and Lee, 2003) have appeared that challenge the efficacy of external focus instruction for novice learners, question the concept of differential levels of automaticity and highlight methodological problems associated with the focus of attention literature.

Using a chipping task, Wulf *et al.* (1999) found that external focus instructions enhanced the performance of novices relative to internal focus instructions. Perkins-Ceccato *et al.* (2003) report a similar study; however, whilst experts' performances were superior under external focus conditions, novices performed better under internal focus instructions. This latter finding is striking because virtually all previous research has involved novice performers. Minor differences between the two experimental protocols in terms of instructions given to participants may render the two studies incomparable, but highlights the fragility of instructional nuances.

In a more compelling failure to replicate the benefits of external focus, Maxwell and Masters (2002) proposed an alternative explanation of the focus of attention effect, based on their concepts of explicit and implicit motor learning (Masters, 1992; Maxwell, *et al.*, 2000; Maxwell, *et al.*, 2001; Maxwell, *et al.*, 2003; Masters and Maxwell, 2004). They argued that the external learner's attention is drawn to only one source of information, that which is external to the performer. Internal focus instructions direct attention to internal information but, crucially, salient external information, such as where a chipped ball lands, is also processed. In effect, internal focus instructions impose a greater load on attentional resources or working memory. Increasing load on working memory has been associated with poorer performance in golf putting (Maxwell *et al.*, 2000) and breakdown under secondary task loading (Maxwell *et al.*, 2002; 2003). Thus, relative to the use of an external focus of attention, performance should be lowered and probe reaction times lengthened when an internal focus is adopted, consistent with the findings of Wulf *et al.* (2001).

Based on these premises, Maxwell and Masters (2002) had internal and external focus groups perform a dynamic balancing task (wobble board) over ten 90s learning trials. Participants then performed three 90s retention trials of balancing only, followed by three transfer trials during which they performed a secondary task whilst balancing. Secondary task loading (tone counting) was expected to have a greater impact upon the performance of internal focus learners than on external focus learners. However, Maxwell and Masters (2002) found no differential effects of attentional focus during learning, or retention. Furthermore, the secondary task load had no impact upon performance of the primary balancing task, suggesting that both groups' performances were relatively automatic. As an additional test to ensure instructional compliance (manipulation check) and as a second indicator of the amount of task relevant processing carried out in working memory (i.e. conscious processing), participants were asked to provide post experimental verbal reports of how they had accomplished the task and what they had thought about whilst performing.

Verbal protocols revealed that neither group reported a substantial amount of explicit knowledge (generally, less than two rules) and that there was only a slight overall bias in the type of rules that they reported, suggesting that both groups used internal and external foci interchangeably. Further evidence for this contention was provided by post hoc interviews that revealed that 90% of participants had discovered that an external focus was advantageous to performance and had adopted this strategy rather than the instructed strategy, despite repeated reminders prior to every learning trial. These findings were replicated in a second experiment where augmented feedback presented on a screen in the first experiment was removed to avoid possible confounding effects.

Maxwell and Masters' (2002) results were taken as evidence that learners do not normally rely on a single attentional focus and rapidly switch attention according to task demands despite strict instructions to maintain a specific focus. The lack of manipulation check is a fundamental problem associated with the attentional focus literature, a problem noted by Wulf, Weigelt, Poulter and McNevin (2003). Treatment conditions are assumed, despite evidence that suggests individuals have a preference for an internal attentional focus early in learning, but actively switch to an external focus as learning proceeds. Wulf *et al.* (2001) reported that performers of a balancing task when given the opportunity to focus independently had a preference to attend externally, as it resulted in more effective performance; confirmation of Maxwell and Masters' position. However, Maxwell and Masters' contention that differing amounts of explicit information would be used by the two groups was unsupported. They pointed out that the balancing task is a fairly undemanding task that is unlikely to pose a substantial load for attentional resources to cope with. The use of more complex tasks that do have a substantial attentional requirement and potential for explicit rule accumulation may produce results more compatible with either the common coding/constrained-action hypothesis or the explicit processing hypothesis.

Experiment 1

The experiments conducted by Maxwell and Masters (2002) imply that a complex motor skill should be utilized to clarify the attentional focus effect. Golf putting, has been utilized extensively in this respect because it is novel to many potential participants and, therefore, devoid of pre-established automaticity, a confounding factor in balancing tasks. Furthermore, the skill has relatively explainable movement mechanics allowing the possibility for task relevant knowledge accumulation. The experiment was designed to assess the prediction that performers who focus internally during learning will breakdown under secondary task load as a consequence of acquiring and processing a far greater amount of explicit knowledge in working memory. The alternative hypothesis is that both groups use an equivalent amount of information but that it is the type (internal or external) that is crucial. The study also seeks to clarify whether postulations made in the literature regarding the accelerated learning benefits of an external focus are valid. Verbal protocols were administered to assess the effect of treatment condition on information accumulated and to verify if the manipulation had been administered successfully. Furthermore, participants were placed under secondary task load to quantify degree of automaticity or attentional load imposed by attentional focus requirements.

Method

Participants

Thirty Hong Kong University undergraduates and postgraduates (7 men and 23 women), all naïve to the complex motor skill of golf putting, voluntarily participated in the study after giving their informed consent. Participants were randomly assigned to either an internally focused or an externally focused treatment condition, with equal numbers in each condition. The participants were aged 20-46 years (mean 24.1; s = 5.94).

Apparatus

The task was performed on an artificial grass putting mat, 4m long and 36cm wide. Standard golf balls were placed at a distance 2m from the front of the hole and 15cm left of the holes centre. The cut of the hole was of standard PGA size with the mat rising upward at an incline of 1 in 4, 40cm before the hole. Participants all used the same

MacGregor (EP352L) putter. A PC was used to administer the secondary tone counting task.

Procedure

Participants were allocated to two groups with a different focus of attention. The internally focused group (Internal) was instructed to direct attention to the swing of their hands, whereas the externally focused group (External) was told to focus on the swing of the putter head. The experiment was divided into two distinct phases, a Learning Phase and a Test Phase. Learning consisted of 10 blocks of 30 trials. At the beginning of every block during the Learning Phase participants were reminded where their focus should lie and the importance of maintaining that focus. After each block participants were allowed 1-2 minutes rest except after the fifth block when participants were given a five minute rest during which they completed the Reinvestment Scale (Masters, Polman and Hammond, 1993). The questionnaire was administered to prevent participants compiling task relevant information while resting (results not reported). Additional rest was granted if requested by the participant. Following learning, participants were asked to complete a verbal protocol, in which they reported any movements, methods or techniques they recalled using to complete the task.

The Test Phase immediately followed completion of the verbal protocol and consisted of an A-B-A (retention – transfer – retention) design. Both retention tests consisted of 30 trials in which no instructions were given. The transfer test again was 30 trials in length and required participants to concurrently putt while attending to the secondary task of tone counting. High and low pitched tones were produced from the computer at intervals of 900msec. Participants were told that it was important for them to putt as accurately as possible but at the same time accurately count the high pitched tones. On completion of the 30 trials the participant reported the total number of high pitched tones that they had heard and were informed of their accuracy. Following the second retention test the participants were thanked and debriefed.

Analysis

Accuracy on the putting task was scored as total number of successful putts per block of 30 trials; thus, a minimum of zero and a maximum of 30 points could be scored. Analysis of putting performance was performed using multivariate analysis of variance (MANOVA) with repeated measures, reporting Wilks' Lambda probabilities. Verbal protocols were scored by two independent raters who counted the number of rules reported as either internal (e.g. swing the hands smoothly) or external (e.g. swing the club smoothly) in nature. Pearson's Product Moment Correlation Coefficient, calculated to assess inter-rater reliability, produced a significant correlation for both internal (r = .84, P < .001) and external (r = 0.78, P < 0.001) rules. The scores from the independent raters were thus averaged to provide a mean number of external and internal rules for each treatment condition. Secondary task performance was calculated as percentage concordance between the number of high tones reported and the actual number of high tones.

Results

Learning

The equivalency of initial performance was assessed using a one-way ANOVA taking score on the first ten trials as the dependent measure. No group differences were found ($F_{1,\ 28}$ = 0.08) and mean performance was poor (Internal = 1.06, External = 1.20), suggesting that they were equally unfamiliar with the task. To assess the performance of the groups throughout learning a Group x Block (2 x 10) MANOVA with repeated measures was performed taking putting performance as the dependent measure. This revealed an effect of Block ($F_{9, 20} = 6.45$, $P < 0.001$), but not of Group ($F_{1, 28} = 0.09$, $P = 0.77$). An interaction was not evident ($F_{9, 20} = 0.91$, $P = 0.54$). It is apparent that both groups improved in a similar manner as a consequence of practice (Figure 1).

Figure 1 near here

Test Phase

To ascertain the effect of the treatment conditions on retention and transfer under a secondary task load, a 2 x 3 (Group x Block) MANOVA with repeated measures was computed. Although there was no effect of Block ($F_{2, 27} = 1.90$, $P = 0.17$) or Group ($F_{1, 28} = 0.34$, $P = 0.57$), an interaction was found between Block and Group ($F_{2, 27} = 4.04$, $P < 0.05$). To assess the cause of the interaction, post-hoc analysis was performed using a one-way analysis of variance with repeated measures and pair-wise comparisons where appropriate. While no group differences were evident in the retention blocks (both $P > 0.54$), a significant difference was shown between the conditions in the transfer test ($F_{1, 29} = 4.36$, $P < 0.05$). Furthermore, no effect of Block was present in the external focus condition ($F_{2, 13} = 2.09$, $P = 0.16$), but an effect was found in the internally focused condition ($F_{2, 13} = 8.37$, $P < 0.01$). This effect for the internal group was further examined using pair-wise comparisons between individual blocks. No differences were apparent between the two Retention blocks ($P = 0.52$); however, performance in the transfer test was significantly poorer than both Retention 1 ($P < 0.05$) and Retention 2 ($P < 0.005$). The Group x Block interaction in the test phase was caused by deterioration in putting performance under secondary task load in the internal focus condition only (Figure 1).

Secondary task tone counting

One-way analysis of variance identified a non-significant difference ($F_{1,\ 28} = .68$, $P = 0.42$) between the groups. Furthermore, a bivariate correlation calculated a non-significant relationship ($r = 0.16$; $P = 0.39$) between tone counting accuracy and performance difference from retention to transfer. This implies that both the internal (mean 93.3%) and the external (mean 91.2%) groups were equally proficient on the secondary task and that differential tone counting accuracy did not account for the performance differences in the test phase.

Verbal Protocol

A Group x Rule Type (2 x 2) MANOVA taking mean number of rules reported in the verbal protocols as the dependent variable, produced both a main effect of Group ($F_{1,\ 28} = 4.30$, $P < 0.05$), and of Rule Type ($F_{1,\ 28} = 17.80$, $P < 0.001$); furthermore, an interaction was found between the two ($F_{1,\ 28} = 4.13$, $P < 0.05$). Post hoc analysis showed significant between group differences in the quantity of internal rules ($F_{1,\ 28} = 5.45$, $P < 0.05$), but not external rules ($F_{1,\ 28} = .27$, $P = 0.61$). Figure 2 indicates that this difference is due to the higher mean number of internally based rules reported by the internally focused group. Paired samples t-tests indicated that the pattern of rules reported in the internal focus condition was as expected, with a greater quantity of internal rules ($P < 0.001$). Surprisingly, the pattern of rules reported in the external condition did not show a greater quantity of external rules (*P* = 0.20; Figure 2). These results suggest that the internal group processed a greater amount of internally referenced explicit information whilst putting. No significant correlations were found between change in performance under secondary task loading and number of explicit rules reported.

Figure 2 near here

Discussion

Evidence from the attention focus literature has demonstrated benefits of learning with an external focus of attention; however, the present experiment failed to replicate these benefits using a golf putting skill. Attention in the experiment was manipulated toward internal movements made by the individuals (internal group) or the movement's effect (external group). No differences were found between groups during either learning or retention. Differences between the two focus conditions only became apparent when a secondary task load was introduced, with detrimental performance effects evident in the internal focus group. Breakdown in skill is evident under secondary task load when attentional or working memory capacity is breached (Maxwell *et al.*, 2003) or when there is structural interference. The breakdown of motor skill under secondary task loading in the internally focused group appears to have been the consequence of loading working memory with an excessive amount of explicit, internally referenced, task relevant knowledge. Information from the post-learning verbal reports suggests that similar amounts of external knowledge were accumulated in both the external and internal focus condition; whereas, the internal focus group accumulated significantly more internal rules than the external focus group. It appears, therefore, that the presentation of a single internal awareness cue during learning promotes a greater inclination to process information pertaining to the movement processes underlying the task and also, crucially, information about movement effects. Presentation of a single external awareness cue, however, promotes the processing of movement effect information, but retards the processing of explicit information about body mechanics.

Experiment 2

The fundamental question arising from the first experiment is the causality of skill failure under secondary task loading. It is unclear whether performance degradation in the internally focused condition was a function of working memory loading with general explicit task knowledge or with internal information specific to the movement processes involved in skill execution. If the cause of skill breakdown is due to the imposition of a general load on attention then providing both the external and internal groups with an equivalent amount of excessive information to process should result in both groups' performances degrading under secondary task loading. If, however, only the quiddity of internally focused information is crucial to skill breakdown then the provision of a large amount of externally focused information should not result in skill breakdown.

Method

Participants

Thirty-nine volunteers (15 men, 24 women) from the University of Hong Kong gave their informed consent to participate in the study. The golf putting task was a novel experience for all participants. The subjects (mean 20.4 years; $s = 3.84$) were randomly assigned to either an internal ($n = 19$) or an external ($n = 20$) focus condition.

Apparatus

The task was performed on the same surface as in Experiment 1. A square (12 cm x 12 cm) served as the main target and was marked on the surface so that the front edge was 2m from where the balls were placed. A second square (36 cm x 36 cm) was marked concentric to the main target. Balls that came to rest within the main target area received a score of eight points, whereas balls that finished in the larger square scored a single point. This scoring system was employed because the main target was 1/8th the size of the larger square and provides a measure comparable with the in/out measure employed in Experiment 1. A Sony TRV38E Digital video camera was focused on the target area to allow post hoc scoring. Standard two piece balls and a MacGregor (EP352L) putter were used to perform the task. A computer produced the tones for the secondary task.

Procedure

The procedure was identical to Experiment 1 except for the instructions given to participants. Participants were allocated to either internal focus or external focus conditions and were informed that they would be required to perform a golf putting task, with the objective to have the ball finish in the inner square. Based on the results of verbal protocols in Experiment 1, the provision of six rules relating to either external or internal attentional focus learning conditions was expected to provide sufficiently increased attentional loading, with both groups requiring working memory to consciously process the information in order to perform the motor skill. The rules were matched across the conditions so that the focus of attention was either placed on mechanical processes (internal focus) or on the effects of the movement (external focus; see Table 1). Before the experiment commenced, the instructions were explained to the participants so that the meaning of each rule was fully understood. Participants were reminded of the rules and the importance of following them prior to each block in the learning phase. At no time did the experimenter give additional information or physically demonstrate the rules. Verbal protocols were administered post-test rather than post-learning in this study to ensure maintenance of focus throughout the experiment.

Table 1 near here

Analysis

To assess putting performance, MANOVA with repeated measures taking mean score per block was employed, reporting Wilks' Lambda probabilities. The number of internal and external focus rules verbally reported by the participants was evaluated by two independent raters. The rules were categorized into five Rule Type classifications in each condition. Rules reported were rated as either internal old (one of the six rules given by the experimenter), internal new (newly generated internal rules; e.g. keep wrists firm), external old (one of the six rules given by the experimenter), external new (any rule related to an external focus; e.g. strike the ball with the middle of the club head) or neutral (internal or external focus unspecified; e.g. swing smoothly). Inter-rater reliability was calculated using total number of rules reported. A significant correlation was found ($r = .86$, $P < 0.001$) so the mean number of rules was computed by combining the scores of the independent raters.

Results

Learning

A one-way ANOVA, with performance on the first ten trials as the dependent measure, showed no difference between groups ($F_{1, 37} = 0.03$); both groups were equally unskilled. Putting performance in the learning phase was assessed using a Group x Block (2 x 10) MANOVA with repeated measures. This analysis revealed an effect of Block ($F_{9, 29} = 10.10$, $P < 0.001$), but neither an effect of Group ($F_{1, 37} = 0.40$, $P = 0.53$), nor an interaction ($F_{9, 29} = 0.86$, $P = 0.57$). Both conditions improved uniformly throughout practice (Figure 3).

Figure 3 near here

Test Phase

To determine the effect of focus of attention on retention and transfer to a secondary task a Group by Block (2 x 3) MANOVA with repeated measures was computed. This analysis revealed a main effect of Block ($F_{2, 36} = 6.27$, $P < 0.005$) but no significant effect of Group ($F_{1, 37} = 0.34$, $P = 0.56$). Furthermore, no interaction was found between Block and Group ($F_{2, 36} = 0.88$, $P = 0.42$). Post hoc comparisons between the three blocks showed no difference between performance in the two retention blocks ($P = 0.30$). Differences were evident for performance on the transfer test compared to score on both the first ($P < 0.05$) and second ($P < 0.01$) retention blocks. As illustrated in Figure 3, it is apparent that performance deteriorated similarly for both treatment conditions as a consequence of transfer to the secondary task load.

Secondary task tone counting

Percentage concordance was evaluated for accuracy on the tone counting task. One-way analysis of variance identified no difference between the groups ($F_{1, 36} = 0.06$, $P = 0.81$). Mean counting accuracy was 88.4% for the internal group and 89.4% for the external group. Furthermore, a bivariate correlation found the relationship between tone counting accuracy and performance difference between retention and transfer to be non-significant ($r= 0.04$; $P = 0.81$). This implies that the groups were equally proficient at tone counting and that tone counting performance was not sacrificed to improve putting performance.

Verbal Protocol

Figure 4 presents the pattern of rules reported in the two treatment conditions. A 2 x 5 (Group x Rule Type) MANOVA with repeated measures revealed no effect of Group ($F_{1, 37} = 1.78$, $P = 0.19$), indicating that the overall number of rules reported by each group was equivalent (i.e. quantity of rules was comparable). An effect of Rule Type ($F_{4, 34} = 4.28$, $P < 0.01$) was evident; fewer new external rules were reported by either group compared with all other types of rule ($P < 0.03$ in all cases). A Group x Rule Type interaction ($F_{4, 34} = 14.99$, $P < 0.001$) was also found. Post hoc analysis using one-way ANOVA (equivalent to t-test since the presence of two groups precludes the use of Tukey’s test), taking each rule type as separate dependent variables, revealed significant effects for old internal rules ($F_{1,38} = 29.56$, $P < 0.001$) and old external rules ($F_{1,38} = 27.30$, $P < 0.001$) only. The internal group reported more old internal rules than the external group; the effect was reversed for old external rules. The interaction effect was further examined using pair-wise comparisons, which revealed that the internal group reported significantly more original internal rules given to them (Internal Old) than new internal rules ($P < 0.05$) or external rules ($P < 0.005$). The internal group also reported significantly more neutral rules than external rules (*P* < .05). In the external focus condition a significantly greater number of external old rules than any other rule type (*P* < 0.001) was reported; also, the external group reported fewer internal old rules than any other type (*P* < 0.01). No significant differences were found between any other rule types (*P* > 0.05). These findings suggest that the manipulations focused attention in the required direction in both treatment conditions (i.e. maintained differential attentional focus information quality), although both groups did accumulate other task relevant information. Again, no consistent correlations between number of rules reported and change in performance under secondary task loading were found. This was probably because participants tended to report the rules they were given and accumulated few new rules.

Figure 4 near here

Discussion

The second experiment examined the hypothesis that disruption to the performance of the internal focus group under secondary task loading in the first study was a consequence of accumulating a large pool of explicit information, rather than focusing internally. Both external and internal conditions received six focus relevant instructions so that they would have an equal quantity but not quality of explicit knowledge. Performance in both groups was disrupted by secondary task loading. Internal group participants reported mostly internal rules, whereas mostly external rules were reported by members of the external group. Thus, a corruption of focus can be substantially ruled out as a possible reason for degradation of the external group's performance. Verbal protocols also revealed that participants in each group reported using a similar quantity of rules to aid their performance, suggesting that attentional overload is the causative factor rather than an internal focus per se.

In Experiment 1 no performance differences were found between groups during learning and retention; however, both groups acquired information that was relevant to the competing focus of attention. This muddying of the knowledge pool may have accounted for the lack of performance differences, since neither group could be considered purely internal or external. Unlike the first experiment, however, it appears that the provision of six instructions in Experiment 2 successfully maintained attentional focus for the vast majority of the experience. Despite this, failure to provide support for the benefits of an external focus during learning persists. Again, the treatment condition had no differential effect on either learning or retention.

General Discussion

The primary aim of this research was to compare the validity of two competing hypotheses that explain the phenomenon of enhanced learning and performance when learning under an external attentional focus as opposed to an internal attentional focus. The first hypothesis, common coding/constrained-action, postulates an enhancement of automatic processing when focusing externally, due to the compatibility between planning, action and perception. The second hypothesis, conscious processing, cites working memory load as the source of performance differences, with internal focus instructions generating a greater load than external focus instructions and, thus, poorer performance. Two experiments were conducted to compare these hypotheses; external focus instructions were expected to enhance learning and retention performance. Differential effects of secondary task loading were predicted during Experiment 1 but not Experiment 2 in support of the latter hypothesis.

The results of Experiment 1 supported the argument that internal focus instructions lead to the processing of a larger quantity of explicit, internally referenced, information in working memory than external focus instructions. The performance of the internal focus group deteriorated under secondary task loading, whereas that of the external focus group remained robust, suggesting that the internal group's motor performance was reliant on the availability of working memory resources. Verbal protocols confirmed that the internal focus group reported using a greater number of explicit rules, specifically relating to internal aspects of movement control, to aid their performance than the external focus group. However, because the two groups reported a differential number of explicit rules and they received different focus of attention instructions, it cannot be conclusively determined which factor is responsible for the performance differences under secondary task loading. That is, quantity is confounded by quality, such that the results of Experiment 1 support both Wulf's and Masters' contentions.

If an external focus allows the performer to utilize 'more natural control mechanisms' (McNevin *et al.*, 2003; p.22), as is postulated in the constrained action hypothesis, it could be predicted that robustness under secondary task loading would be expected even if a significant number of (external) rules were accumulated during learning. Masters and colleagues, however, would argue that rule accrual of any type should lead to working memory overload and performance breakdown.

The second experiment was designed to determine whether number of rules or focus of attention mediated the performance breakdown of the internal focus group in Experiment 1. Both internal and external focus groups were provided with a set of six internal or external focus instructions so that quantity of information was controlled independently of quality of information. According to the constrained-action theory, the external focus group should still remain robust under secondary task loading due to the enhanced compatibility of the information with planning and action, resulting in reduced attentional requirement. The conscious processing theory, however, predicts that the working memory of both groups should be overloaded and both should perform poorly under secondary task loading. The results supported the latter theory, both group's performances deteriorated, suggesting working memory overload.

It is not surprising in Experiment 1 that the internal focus group acquired a substantial knowledge base during learning. Intuitively, a learner when supplied with a lone piece of information through an extensive number of trials is likely to generate additional information about the task. If not controlled for, task relevant information can be acquired from a range of both internal (e.g. proprioceptive information) and external (e.g. knowledge of results) feedback sources (Maxwell, *et al.*, 2003). Internal learners had an opportunity to build up both internal and external knowledge, as they were directed to attend internally and were aware of the task goal and had feedback regarding the success of their movements (external information).

A surprising observation is that despite the availability of time and attentional resources external learners did not generate as much information. This observation suggests that, to some extent, external focus instructions distract the learner's attention away from internal information that may build up to a level that interferes with task performance. This finding has been reported before by Liao and Masters (2002). Liao and Masters had participants learn a top-spun forehand shot in table tennis and found that a single (externally focused) analogy instruction prevented explicit rule build up. Analogy learners were also robust to the effects of secondary task load on performance.

The predisposition to adopt a particular focus may be dependent on the nature of the skill performed and attentional focus may change throughout learning, in response to changing demands. Evidence suggests that as individuals start to make errors they begin to test hypotheses in an attempt to rectify the unwanted movement effect (Maxwell *et al.*, 2000). In other the words, they switch attention from one aspect to another dependent on the perceived relevance of information from that source. Taking a practical example, a golfer hitting balls on a driving range, may begin attending exclusively to the external effect of the shot, but, as soon as the player observes from their external focus that the ball is slicing right, they may begin to focus internally by altering their stance, swing planes or grip in order to rectify the unwanted effect. Once the effect has been corrected the player may return to an external focus. It is possible that external focus instructions prevent switching of attention, although little evidence for this possibility is apparent other than the reported preference for an external focus by Wulf *et al.* (2001) and Maxwell and Masters (2002).

Previous studies have reported a learning and performance advantage for external focus instructions relative to internal focus or no instructions (e.g. Shea and Wulf, 1999; Wulf *et al.*, 1999). No learning advantages were found in either of the experiments reported here using the putting task or in previous work by Masters and Maxwell (2002) using a dynamic balancing task. These findings are rather puzzling, particularly given the relatively large number of participants and learning trials utilized in this study and the substantial number of replications provided by Wulf and her colleagues. Task complexity could be considered a confounding factor in the present studies. Previous work that has shown learning differences utilizes motorically more complex skills (e.g. golf chipping); however, this does not provide an explanation for the lack of performance differences found in the experiments reported here. When the primary task is performed alone performance differences may not be apparent because working memory capacity is adequate. When a secondary task is added, as in the transfer tests used here, working memory capacity is reduced and may now be breached by differing attentional demands of the primary task. Experiment 1 supports the notion that the internal group process more explicit information than the external group but do not perform differently because working memory is sufficient. When working memory is overloaded by the addition of a further load, only then are performance differences apparent.

There is one clear protocol difference that may provide an explanation of the focus of attention effect. In all the studies conducted by Wulf *et al.* retention tests have been conducted a day after the completion of the learning trials. Recent work in the motor learning literature has implicated sleep as an essential ingredient in learning maximization (e.g. Walker, Brakefield, Morgan, Hobson and Stickgold, 2002). Walker has recently proposed a theory of motor learning consolidation involving stabilization and enhancement (Walker, in press). Stabilization occurs immediately after practice and involves the maintenance of what is learned; however, enhancement involves additional or enhanced learning and relies on sleep.

It is possible that the benefits of an external focus of attention are also dependent on this process of consolidation and sleep dependent enhancement; however, the apparently retarded effect for an internal focus of attention requires further explanation. Walker (2002) claims that the effect of sleep dependent enhancement may be more protracted for declarative knowledge, citing the lack of consistency in research on this topic; in other words, more than one night's sleep is required to evidence enhancement effects. The role of sleep in procedural learning is considerably more consistent with most studies highlighting the beneficial effects after a single night of sleep. In light of our findings that internal focus learners seem to rely on declarative information to a greater extent than their external focus counterparts, a tentative proposal is that if sleep dependent enhancement is confined, at least in the short term, to procedural knowledge then we would expect learners who have developed such knowledge to a greater extent during learning to reap greater benefits from a night's sleep. This prediction holds regardless of the approach taken, constrained-action or conscious processing, since both offer plausible mechanisms for the differential promotion of declarative and procedural knowledge acquisition for external and internal focus learning.

Conclusions drawn from the present work suggest that during the early stage of skill acquisition, external focus instructions effectively reduce the load on working memory rather than promote automaticity (although subsequent automatic functioning may be achieved after protracted practice). Performers actively seek out the most efficient sources of information and do not adhere to specific instructions despite repeated reminders and encouragement, which may ultimately interfere with any instructional program. Manipulation checks should be employed in future studies if any strong conclusions about the efficacy of instructional protocols are to be made. Furthermore, the effects of consolidation and long term retention of motor skills should be investigated to elucidate the effects of factors other than the instructional set (e.g. sleep). It appears that limited external focus instructions may be beneficial to learning and performance, but the mechanism by which they operate is still under debate.

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Captions

Figure 1: Mean number of successful putts made by the Internal Focus and External Focus groups through the learning and test phases (retention (R1 and R2) and transfer (T1)).

Figure 2: Mean number of internal and external rules reported by each group in the verbal protocol.

Figure 3: Mean scores through the learning and test phases (retention (R1 and R2) and transfer (T1) for the internal focus and external focus groups.

Figure 4: Mean number of internal old and new, external old and new, and neutral rules reported by each group in the verbal protocol.

Table 1: Rules given to the focus of attention groups during learning.

Figure 1

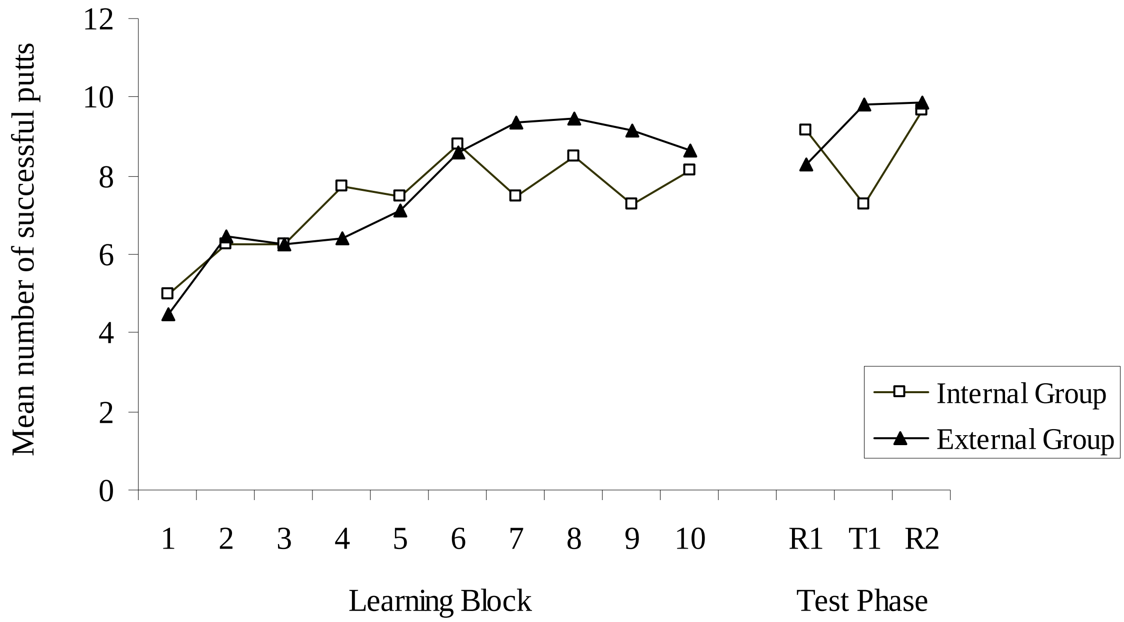

Mean number of successful putts
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
R1
T1
R2
Learning Block
Test Phase
Internal Group
External Group

Figure 2

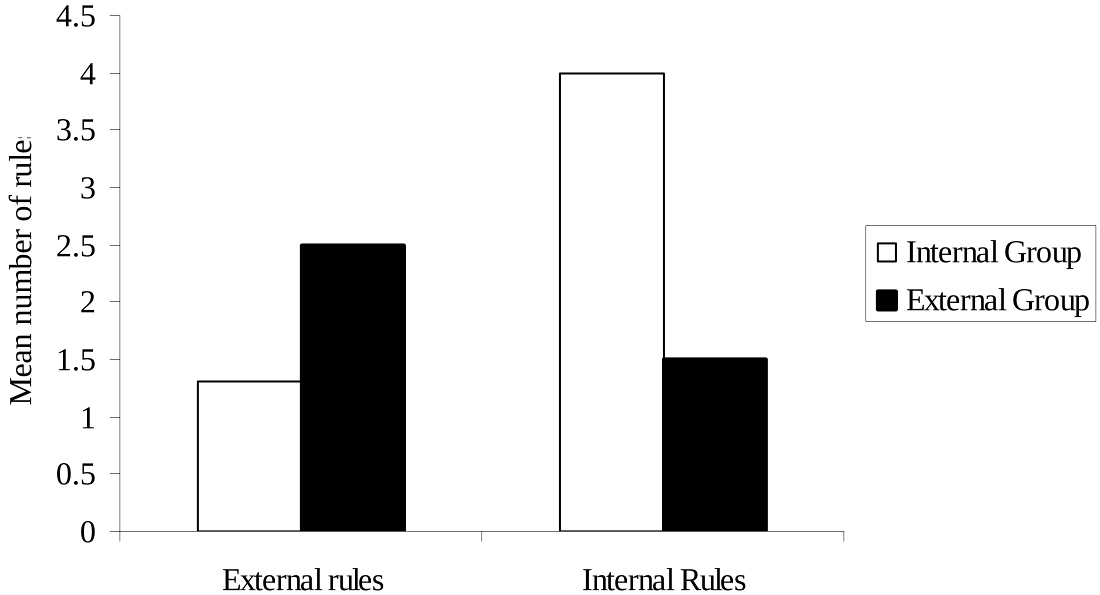

4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Mean number of rule
External rules
Internal Rules
Internal Group
External Group

Figure 3

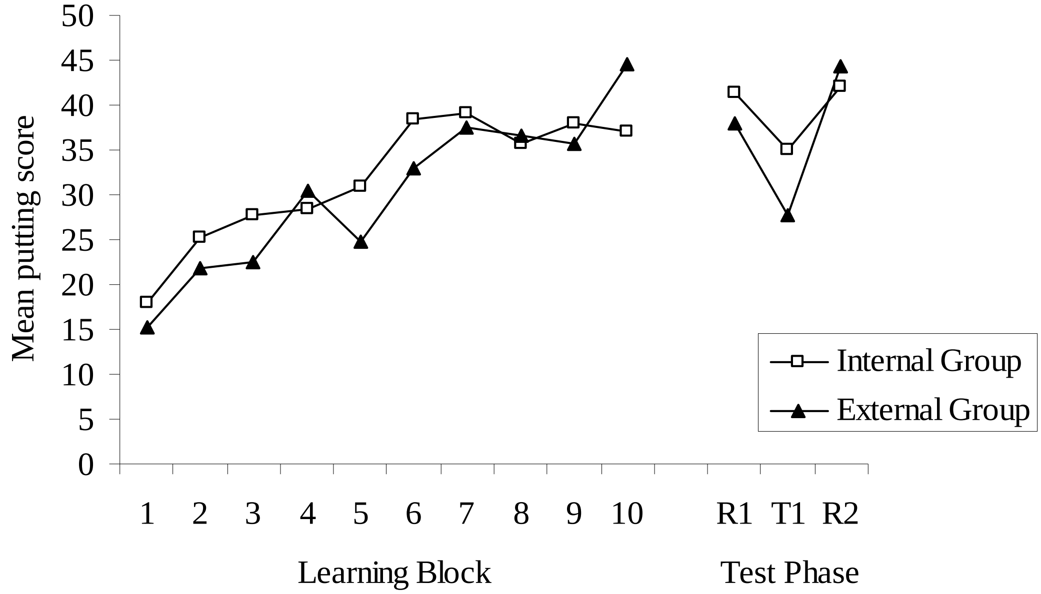
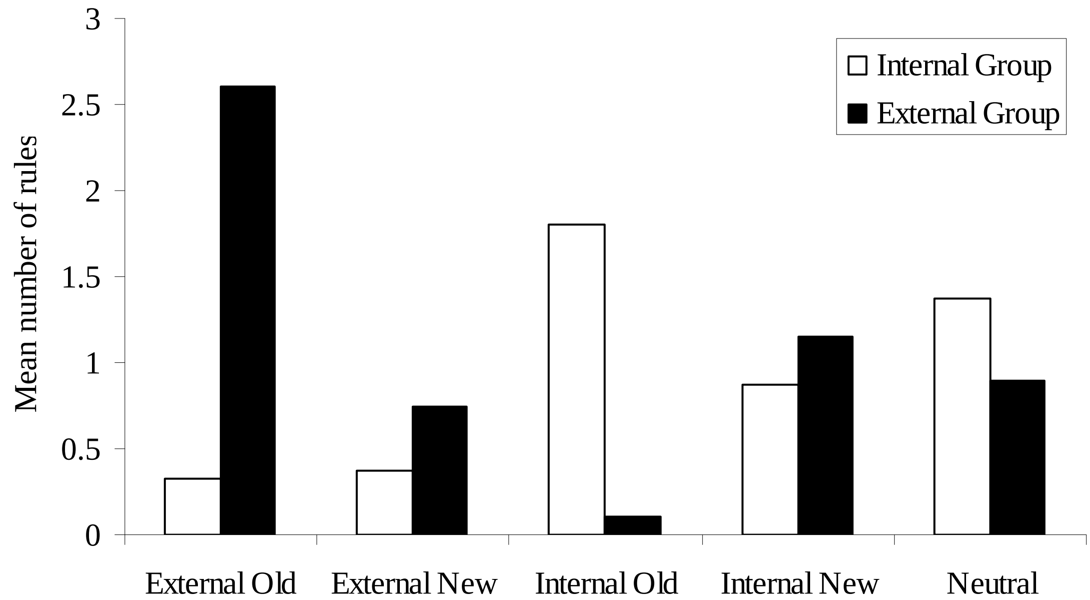

Mean putting score
50
45
40
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10
R1 T1 R2
Learning Block
Test Phase
Internal Group
External Group

Figure 4



3
2.5
2
1.5
1
0.5
0
Mean number of rules
Internal Group
External Group
External Old
External New
Internal Old
Internal New
Neutral

Table 1

Internal Rules	External Rules
Move your **hands** back a short distance	Move the **club** back a short distance
Swing your **hands** forward with a smooth action along a straight line	Swing the **club** forward with a smooth action along a straight line
Allow your **hands** to continue swinging a short distance after contact with the ball	Allow the **club** to continue swinging a short distance after contact with the ball
Adjust the speed of your **hands** so that the correct amount of force is applied	Adjust the speed of the **club** so that the correct amount of force is applied
Adjust the angle of your **hands** to attain the correct direction	Adjust the angle of the **club** to attain the correct direction
Keep your head still for a few seconds after hitting the ball	**Focus on the ground** for a few seconds after hitting the ball